AEROMETRIC MONITORING PROGRAM PLAN FOR THE CALIFORNIA REGIONAL $PM_{2.5}/PM_{10}$ AIR QUALITY STUDY

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List of Acronyms

°C	degrees Celsius
µg	microgram
µm	micron or micrometer
AA	Atomic Absorption
AC	Automated Colorimetry
ACPM	Ambient Carbon Particulate Monitor
ACS	American Chemical Society
AGL	Above Sea Level
AIRS	Aerometric Information Retrieval System
AMTIC	Ambient Monitoring Technology Information Center
APNM	Automated Particle Nitrate Monitor
APS	Aerodynamic Particle Sizer
ASOS	Automated Surface Observing System
ASTM	American Society for Testing Materials
ATOFMS	Aerosol Time Of Flight Mass Spectrometry
b_{abs}	light absorption
BAM	Beta Attenuation Monitor
b_{ap}	particle light absorption
BC	black carbon
b_{ext}	light extinction
b_{sp}	particle light scattering
CAC	Correlated Acceptable Continuous
CAMMS	Continuous Ambient Mass Monitoring System
CEIDARS	California Emission Inventory Development and Reporting System
CFR	Code of Federal Regulations
CIMS	Chemical Ionization Mass Spectrometry
CMB	Chemical Mass Balance
CMSA	Consolidated Metropolitan Statistical Area
CMZ	Community Monitoring Zone
CNC	Condensation Nuclei Counter
CO	carbon monoxide
CO_2	carbon dioxide
COH	Coefficient Of Haze
CORE	Community-Oriented site (or COmmunity-REpresentative site)
CRPAQS	California Regional $PM_{10}/PM_{2.5}$ Air Quality Study
DIAL	DIfferential Absorption Lidar
DIC	DIChotomous sampler
DMPS	Differential Mobility Particle Sizer
DNPH	dinitrophenylhydrazine
DOAS	Differential Optical Absorption Spectroscopy
DRUM	Davis Rotating-drum Universal-size-cut Monitoring impactor
EAA	Electrical Aerosol Analyzer
EC	elemental carbon

List of Acronyms

ECD	Electron Capture Detection
FEM	Federal Equivalent Method
FPD	Flame Photometric Detector
FRM	Federal Reference Method
FTIR	Fourier Transform InfraRed spectroscopy
GC	Gas Chromatography
GIS	Geographic Information System
H_2SO_4	sulfuric acid
HNO_3	nitric acid
HPLC	High Performance Liquid Chromatography
IC	Ion Chromatography
IMPROVE	Interagency Monitoring of PROtected Visual Environments
IMS-95	1995 Integrated Monitoring Study
km	kilometer
L/min	liter per minute
LAMMS	Laser Microprobe Mass Spectrometer
LED	Light Emitting Diode
LIDAR	LIght Detecting And Ranging
LPFF	Laser Photolysis Fragment Fluorescence
LWC	Liquid Water Content
m	meter
m^3	cubic meter
mb	millibar
mm	millimeter
Mm^{-1}	inverse megameters
MPA	Metropolitan Planning Area
MS	Mass Spectrometry
MSL	Mean Sea Level
MSA	Metropolitan Statistical Area
mW	milliwatt
NAAQS	National Ambient Air Quality Standards
NAMS	National Air Monitoring Stations
NARSTO	North American Research Strategy for Tropospheric Ozone
NASA	National Aeronautics and Space Administration
Nd:YAG	Neodymium Yttrium Aluminum Garnet
NFRAQS	Northern Front Range Air Quality Study [Colorado]
NGM	Nested Grid Model
NH_3	ammonia
NH_4^+	ammonium
NH_4HSO_4	ammonium bisulfate
NH_4NO_3	ammonium nitrate
$(NH_4)_2SO_4$	ammonium sulfate
NIST	National Institute for Standards and Technology
nm	nanometer

List of Acronyms

NMHC	Non-Methane Hydrocarbons
NMOG	Non-Methane Organic Gases
NO_2	nitrogen dioxide
NO_3^-	nitrate
NO_X	nitrogen oxides
NPS	National Park Service
OAQPS	Office of Air Quality Planning and Standards [U.S. Environmental Protection Agency]
OC	organic carbon
OPC	Optical Particle Counter
ORD	Office of Research and Development [U.S. Environmental Protection Agency]
PALMS	Particle Analysis by Laser Mass Spectrometry
PAMS	Photochemical Assessment Monitoring Station
PM	suspended Particulate Matter
PM_{10}	suspended Particulate Matter with aerodynamic diameters less than 10 microns (µm)
$PM_{2.5}$	suspended Particulate Matter with aerodynamic diameters less than 2.5 microns (µm)
PMSA	Primary Metropolitan Statistical Area
ppb *or* ppbv	parts per billion volume
ppt *or* pptv	parts per trillion volume
PSAP	Particle Soot/Absorption Photometer
PUF	polyurathane foam
RASS	Radio Acoustic Sounding System
RH	Relative Humidity
ROG	Reactive Organic Gas
RSMS	Rapid Single-particle Mass Spectrometer
S	sulfur
SAQM-AERO	SARMAP Air Quality Model with aerosol module
SCAPE	Simulating Composition of Atmospheric Particles at Equilibrium model
SJV	San Joaquin Valley
SLAMS	State/Local Air Monitoring Stations
SMPA	Scanning Mobility Particle Analyzer
SO_2	sulfur dioxide
$SO_4^=$	sulfate
SOA	Secondary Organic Aerosol
SPM	Special Purpose Monitor
SSI	Size-Selective Inlet
SUVA®	DuPont refrigerant used as calibration gas
SVOC	Semi-Volatile Organic Compounds
TDLAS	Tunable Diode Laser Absorption Spectroscopy
TEOM	Tapered Element Oscillating Microbalance

List of Acronyms

TOG	Total Organic Gases
TSP	Total Suspended Particles
UAM-AERO	Urban Airshed Model with Aerosol Module
U.S. EPA	U.S. Environmental Protection Agency
UTC	Coordinated Universal Time
VOC	Volatile Organic Compounds
WINS	Well Impactor Ninety-Six $PM_{2.5}$ inlet
XAD	absorbing resin

1. INTRODUCTION

Central California is a complex region from an air quality and meteorological perspective, owing to its proximity to the Pacific Ocean, its diversity of climates, and its complex terrain. Within central California, the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) and the Great Basin Air Pollution Control District (GBAPCD) have been designated to be in serious non-attainment of the 1987 National Ambient Air Quality Standards (NAAQS) for particulate matter (PM) and are required to implement emissions reduction measures. Although the area administered by the Bay Area Air Quality Management District (BAAQMD) has not been designated as non-attainment, measured 24-hour PM_{10} (suspended particles with aerodynamic diameters less than 10 μm) concentrations in San Jose have exceeded 150 $\mu g/m^3$. Reduced visibility in the Mojave Desert, and even in the Grand Canyon, has been attributed, at least in part, to $PM_{2.5}$ (suspended particles with aerodynamic diameters less than 2.5 μm) exiting the San Joaquin Valley through the Tehachapi Pass.

The California Regional $PM_{10}/PM_{2.5}$ Air Quality Study (CRPAQS) intends to improve scientific understanding of excessive PM levels in central California. Specifically, this understanding is needed to determine where and when populations experience excessive exposures, as defined by NAAQS and state air quality standards, and how to cost-effectively reduce those exposures to acceptable levels. CRPAQS is an integrated effort that includes air quality and meteorological field measurements, emissions characterization, data analysis and air quality modeling. CRPAQS activities are complementary to long-term monitoring and research activities being conducted by the California Air Resources Board (ARB) (Turkiweicz and O'Brian, 1998), the U.S. Environmental Protection Agency (EPA), the SJVUAPCD, the BAAQMD, the GBAPCD, and other air quality districts in the region.

This document specifies measurements to be taken in central California between December 1999 and January 2001 to meet the objectives of the CRPAQS through data analysis and numerical simulations. It describes the study area, its emissions and meteorology, and hypotheses about the causes of high particle concentrations. It identifies measurement locations, observables, and monitoring methods. It specifies data management and reporting conventions and outlines the activities needed to ensure data quality.

1.1 $PM_{2.5}$ and PM_{10} Air Quality Standards

PM has been shown to adversely affect public health when susceptible populations are exposed to excessive concentrations (U.S. EPA, 1996; Vedal, 1997). NAAQS for PM have been established to minimize the adverse effects of PM on the majority of U.S. residents. The NAAQS apply to $PM_{2.5}$ and PM_{10} mass concentrations and are described as follows (U.S. EPA, 1997):

- Twenty-four hour average $PM_{2.5}$ not to exceed 65 $\mu g/m^3$ for a three-year average of annual 98^{th} percentiles at any community-representative site in a monitoring area.

- Three-year annual average $PM_{2.5}$ not to exceed 15 $\mu g/m^3$ concentrations from a single community-representative site or the spatial average of eligible community-representative sites in a monitoring area.

- Twenty-four hour average PM_{10} not to exceed 150 $\mu g/m^3$ for a three-year average of annual 99^{th} percentiles at any site in a monitoring area.

- Three-year average PM_{10} not to exceed 50 $\mu g/m^3$ for three annual average concentrations at any site in a monitoring area.

The $PM_{2.5}$ NAAQS are new. While the PM_{10} NAAQS retain the same values as the prior NAAQS (U.S. EPA, 1987), their form is new. Previously, the PM NAAQS applied to the highest 24-hour or annual averages measured within a monitoring planning area. Monitoring networks were often designed to measure these highest values, even though these networks did not necessarily represent the overall exposure of populations to excessive PM concentrations. Some data from these networks were disregarded by epidemiologists as being unrelated to health indicators such as hospital admissions and death.

The new forms for these standards are intended to provide more robust measures for the PM indicator. While PM_{10} network design and siting criteria are unchanged, new $PM_{2.5}$ monitoring networks to determine compliance or non-compliance are intended to best represent the exposure of populations that might be affected by elevated $PM_{2.5}$ concentrations (Watson et al., 1997).

The statistical form of these standards and the community-oriented monitoring sites used for $PM_{2.5}$ and PM_{10} compliance give low importance to rare occurrences of high concentration values. In fact, the magnitudes of the highest measured concentrations are not even considered (although the existence of these high values determines the percentile values) for designating compliance with the 24-hour standards. The three-year averaging of 98^{th} and 99^{th} percentile concentrations attenuates the influence of an unusual event during a year.

Limited $PM_{2.5}$ measurements from central California indicate that the annual 15 $\mu g/m^3$ standard will probably be exceeded in several populated areas, especially in the San Joaquin Valley. These high annual averages are dominated by elevated concentrations in the cities and in non-urban locations during winter and fall. While a few $PM_{2.5}$ concentrations have exceeded 65 $\mu g/m^3$ during winter, their number is not sufficient, nor are the exceedances so consistent from year to year, that the 24-hour standard is in danger of exceedance. $PM_{2.5}$ constitutes ~80% of PM_{10} during winter and ~50% of PM_{10} during the rest of the year. The annual $PM_{2.5}$ standard is most likely to be exceeded in several parts of central California, and emissions reductions that lower $PM_{2.5}$ concentrations will also lower many excessive PM_{10} levels.

Elevated PM_{10} concentrations with a about equal $PM_{2.5}$ and coarse particle (PM_{10} minus $PM_{2.5}$) components are consistently found during the fall, from September through mid-November. Other PM_{10} exceedances have occurred as isolated events at one or two locations when a nearby activity contributed a large bolus of fugitive dust, or when wind

speeds exceeded suspension thresholds over bare land or lake beds. These situations are typically dominated by the coarse particle fraction. Windblown dust excursions have been most often found in the southern San Joaquin Valley and in the high desert, especially in the vicinity of Owens Lake. PM_{10} 24-hour PM_{10} concentrations during fall in the Hanford/Corcoran area are consistently higher than those measured elsewhere, and the 24-hour and annual PM_{10} NAAQS may be exceeded in this region of the San Joaquin Valley.

These NAAQS will be implemented according to the following schedule:

- **1997:** $PM_{2.5}$ and PM_{10} NAAQS promulgated by EPA

- **1998-2000:** $PM_{2.5}$ compliance networks are installed and operating. PM_{10} networks are revised. Several PM_{10} compliance sites in California will be discontinued in favor of new $PM_{2.5}$ sites.

- **1999:** Metropolitan Planning Areas (MPA) are defined and designated as unclassifiable with respect to $PM_{2.5}$ and PM_{10} standards. Areas with existing or pending PM_{10} State Implementation Plans (SIP) are obligated to implement the measures in those plans.

- **1998-2003:** Compliance data are collected. Special studies are conducted to determine sources and develop control measures. Compliance data are $PM_{2.5}$ and PM_{10} measurements with Federal Reference Methods (FRM) or Federal Equivalent Methods (FEM). Fifty sites in the U.S. will acquire $PM_{2.5}$ samples amenable to chemical characterization for elements, ions, and carbon, year after year. Two hundred and fifty sites will acquire chemical data for shorter time periods and may be moved from one area to another. Several of these will be located in central California.

- **2002:** The five year evaluation of particulate matter health criteria is completed by EPA. By presidential order, no planning areas will be declared in non-attainment until the technical basis for the new standards is evaluated in light of new research.

- **2002-2005:** Presuming the current PM NAAQS are justified by the re-valuation, planning areas exceeding the standards will be assigned attainment or non-attainment status.

- **2005-2008:** SIPs are formulated and submitted to demonstrate how planned emissions reductions will bring the area into attainment of the standard.

- **2012-2017:** Emissions reduction measures are implemented and attainment is demonstrated by $PM_{2.5}$ and PM_{10} concentrations below the NAAQS levels.

The regulatory schedule to implement these standards is on par with the three to ten year schedule needed to extract the science from a major field study (note that scientific papers are still being published using data from the 1987 Southern California Air Quality

Study and the 1990 SJVAQS/AUSPEX study). A major field study from 12/1999 through 1/2001 would have its data complete and validated by the beginning of 2002. Data analysis projects would be completed and published in 2003. Model evaluation and performance testing could be completed by 2004, with modeled control strategy evaluations ready by the 2005 SIP deadline. A study conducted a year or two later, however, would be more similar to the situation encountered at the time of non-attainment designation (in terms of emissions changes resulting from population and technology changes) and improvements in measurement technology. This plan assumes a 1999-2001 study period.

1.2 CRPAQS Field Study Objectives

The CRPAQS programmatic goal is to provide additional and more comprehensive information than is currently available to explain the nature and causes of particulate concentrations and visibility impairment in and around central California. This information is especially needed within the San Joaquin Valley where the highest particle concentrations have been measured in the past. The CRPAQS programmatic goal will elucidate the implications of currently planned emissions reduction strategies and will focus future emissions reduction efforts in those areas where they will have the greatest benefit on air quality for the least cost. This goal is pursued by obtaining and using ambient data, source emissions data, mathematical simulations, and data analysis methods. Specific field study objectives are:

1. Obtain a documented data set, with appropriate data qualification statements, that is suitable for characterizing the nature and causes of particulate concentrations and visibility impairment in and around central California by supporting modeling and data analysis activities.

2. Evaluate the extent to which long-term PM monitoring networks represent the levels to which large populations are exposed and PM concentrations under a variety of emissions and meteorological conditions.

3. Document the current spatial distribution, temporal variation, and intensity of PM concentrations and visibility impairment within central California.

4. Measure and characterize the structure and evolution of the boundary layer and the nature of regional circulation patterns that determine the transport and diffusion of PM and its precursors in central California.

5. Further characterize the source zones of influence and quantify source contributions to community exposure for PM chemical components, including particles that are directly emitted and those that form from directly emitted gases.

6. Quantify source contributions to secondary aerosol, identify the limiting precursors, and assess the extent to which reductions in nitrogen oxides, ammonia, sulfur oxides, and volatile organic compounds would be effective in reducing PM concentrations.

7. Refine conceptual models that explain the causes of elevated PM concentrations and interactions between emissions, meteorology, and ambient PM concentrations.

8. Evaluate and improve the performance of emissions, meteorological, and air quality simulations. Apply simulation methods to estimate PM concentrations at receptor sites and to test potential emissions reduction strategies.

The development of air quality simulation models is not a CRPAQS objective, although the evaluation and use of mathematical simulations are a major CRPAQS activity. Field experiments are intended to acquire the measurements needed for model inputs, parameterizations, and evaluation. Simulation methods are tools that integrate and interpret the meaning of these measurements. CRPAQS field experiments must allow the mechanisms that cause elevated PM levels to be understood, and the mathematical simulations of those methods to be evaluated to determine how well they represent those mechanisms. The CRPAQS measurement strategy involves acquiring data that challenges a model causing a flawed model to reveal its weaknesses. Model improvements and re-evaluation follow, until the full range of challenges is presented and responded to successfully.

CRPAQS measurements are intended to support both source and receptor models. Use of both types of models promotes corroborative testing and analysis, providing added means of evaluation. A complementary CRPAQS Model Evaluation and Validation Plan (Magliano et al., 1998a) describes how models will be used, and this field study plan is completely coordinated with this modeling plan. A complementary CRPAQS Emissions Modeling Plan (Magliano et al., 1998b) describes how emissions estimates will be determined.

1.3 Field Study Plan Objectives

This is the fourth revision to an evolving plan that will be in progress until the field study is complete, at which time it will be revised to reflect what actually took place and to provide a retrospective evaluation of the study design. Previous projects have shown the necessity of this final revision as the field study plan becomes the primary record of what took place and why it took place. While careful planning and coordination are needed in the construction of a major field program, changes are inevitably made in response to unexpected situations that arise and need to be documented.

The objectives of the field study plan throughout its evolution are:

- Clearly define CRPAQS objectives and relate the field measurements to those objectives through coordination with emissions studies, data analysis plans, and modeling plans.

- Define long-term, intensive, and special study measurements with respect to purposes, sampling locations, monitoring periods, measurement frequency, sample duration, and observables measured.

- Integrate recommendations from scientific and regulatory reviewers and provide the rationale for selection or deletion of measurements.

- Evaluate, select, and justify monitoring methods and reconcile costs with available resources.

- Establish common conventions and procedures for data reporting, communications, and quality assurance.

- Specify timelines, schedules, and responsibilities.

- Evaluate and reference relevant work from other studies to minimize repetition of past mistakes.

1.4 Overview of CRPAQS Field Measurements

The CRPAQS field study will consist of a long-term campaign from 12/1/1999 through 1/31/2001, a winter intensive study within the period of 11/15/2000 through 1/31/2001, and a fall intensive study within the period of 9/1/2000 through 10/31/2000. Several experiments will be conducted during the summer period of 7/1/98 through 8/31/98. Details on f these measurements are presented in Sections 4 through 7 of this plan.

1.4.1 Long Term Annual Average Campaign (12/1/1999-1/31/2001)

Long-term measurements are intended to characterize annual average concentrations and their causes. Several air quality and meteorological networks will be operated over a study domain extending from the Pacific Ocean on the west into the Mojave Desert and Owens Valley on the east and from the Tehachapi Mountains in the south to the Sutter Buttes in the north. The most detailed measurements will be focused in the southern San Joaquin Valley where the highest PM concentrations are measured, between Bakersfield and Fresno. The components of the long term campaign are:

- **ARB backbone $PM_{2.5}$ network:** ARB, in collaboration with the California air quality management districts, is establishing $PM_{2.5}$ monitoring sites in central California, several of which will acquire 24-hour mass concentrations every day while others will monitor every third day. Several of these are chemical speciation sites that will obtain samples amenable to elemental, ion, and carbon analyses every twelfth day. Most of these sites have been selected to be community representative and will be used for determining compliance with the $PM_{2.5}$ NAAQS. CRPAQS intends to determine the causes of excessive concentrations that might be measured at these sites.

- **ARB backbone PM_{10} network:** More than 100 PM_{10} have operated, and will continue to operate, at community exposure and source-oriented sites throughout central California. Many, but not all, or these existing PM_{10} monitors will be collocated with $PM_{2.5}$ monitors.

- **ARB air quality network:** Hourly averages are measured by the ARB and the air quality districts at 134 sites for ozone, 78 sites for oxides of nitrogen, 33 sites for sulfur dioxide, 16 sites for light scattering, and 47 sites for light absorption. The measurement frequencies and locations are sufficient for particle monitoring, but data must be reported to the nearest 1 ppb rather than the nearest 10 ppb as is the current practice

- **Integrated surface meteorological network:** This network unifies monitoring data from 8 networks and includes approximately 157 wind speed and direction sites, 122 temperature sites, 60 relative humidity sites, 26 solar radiation sites, and 7 ambient pressure sites.

- **CRPAQS anchor $PM_{2.5}$ network:** This network consists of a few sites that acquire aerosol and precursor measurements with high time-resolution instrumentation at community exposure, transport, and gradient sites. Site locations and instrumentation vary among seasons with the most complete measurements made during the winter. Continuous particle monitors for $PM_{2.5}$ mass, PM_{10} mass, $PM_{2.5}$ carbon, $PM_{2.5}$ light scattering, and $PM_{2.5}$ light absorption will be deployed with averaging times of 5 to 30 minutes. Daily 24-hour $PM_{2.5}$ filter samplers using Teflon and quartz filters will be operated at most anchor sites throughout the year. Relative humidity and wind speed monitors will be enhanced with more sensitive detectors and 5 minute averaging periods at most anchor sites.

- **CRPAQS satellite network:** Satellite sites, consisting of portable battery-powered $PM_{2.5}$ samplers for 24-hour average samples amenable to chemical analyses and battery-powered nephelometers for 5-minute average PM measurements, will be located at interbasin transport sites, intrabasin gradient sites, background sites, and emissions source sites. Interbasin transport sites will be supplemented with surface wind measurements where they are currently lacking. Seven community exposure sites will be equipped with satellite monitors for PM_{10} measurements. Filter samples will be acquired at satellite sites every sixth day throughout the annual study period.

- **CRPAQS upper air network:** Radar profiler wind sounders, RASS vertical temperature sounders, and Doppler sodar wind sounders will acquire time-resolved measurements. These will complement twice per day airsonde launches at Vandenburg, Oakland, Pt. Mugu Naval Air Station, and Edwards Air Force Base. Hourly ceilometer measurements will be obtained from airports in the region that operate these instruments. Several of the radar profilers included in this network are being operated by other agencies on a long-term basis, and more of these may be installed by the end of 1999.

- **CRPAQS micrometeorological tower:** A 100 m tall scaffold-type tower at the a non-urban site between Fresno and Bakersfield will be instrumented with high time-resolution temperature, meteorological, and particle size instruments at five levels. These measurements will be sufficient to detect vertical as well as

horizontal dispersion and mixing characteristics, as well as windblown dust suspension characteristics near ground level, under a large variety of meteorological situations likely to occur throughout the year. It will also serve as an analysis platform for wintertime fog and aerosol chemistry studies and for a fall dust and deposition experiment. The Walnut Grove tower between Sacramento and Stockton will be instrumented in a similar manner during the winter intensive measurement period.

Three preparatory studies are being undertaken prior to initiation of field measurements. Several continuous and filter-based particle monitors will be evaluated at the Bakersfield/California site during January 1999 to determine the optimal combination to be deployed at anchor sites. A winter forecasting scheme will be devised and evaluated during the winters of 1998-1999 and 1999-2000. Winter measurements with portable nephelometers are being taken at different elevations in the Sierra Nevada foothills east of Fresno to evaluate candidates for measurements to be taken near the top of the valleywide pollution layer during the winter monitoring campaign.

1.4.2 Summer Experiments (7/1/2000-8/31/2000)

Three experiments will be conducted during the summer period:

- **$PM_{2.5}$ organic characterization study:** The purpose of this study is to provide a detailed particulate organic speciation of ambient air in an urban area during summer. This will provide a contrast to the annual and winter particle organic measurements and permit the assignment of summertime organic carbon to sources using receptor models. Particle samples amenable to organic speciation will be acquired at the Fresno anchor site on the same sixth day schedule as the annual average chemical characterization. The species measured should be sufficient to distinguish diesel-vehicle exhaust, gasoline-vehicle exhaust (cold start, hot stabilized, and malfunction), burning (agriculture, residential, and wildfire), meat cooking, suspended road dust, and secondary organic aerosol as separate contributors to $PM_{2.5}$.

- **Anchor site at Edwards Air Force Base:** An anchor site oriented toward components of light extinction will be operated in the Mojave desert to evaluate the timing and intensity of light extinction and the aerosol components that cause it.

- **Satellite transport sites from South Coast Air Basin:** Satellite sites using portable nephelometers will be located along transport pathways during the summer period to determine the magnitude, direction, and duration of visibility-reducing atmospheric constituents along pathways from the Los Angeles area for comparison with long-term measurements of these constituents moving from the San Joaquin Valley into the desert.

1.4.3 Winter Campaign (11/15/2000-1/31/2001)

The winter campaign will occur for 60 continuous days to begin between 11/15/2000 and 12/1/2000. This campaign intends to acquire measurements that will increase the understanding of and the capability to simulate the secondary inorganic and organic fraction of $PM_{2.5}$. In addition to continuous air quality measurements over the 60 day period, several episodes of three to eight-day duration, for a total fifteen days, will be selected according to a forecast of PM buildup. The long-term network will operate throughout the 60-day winter campaign period with the following enhancements:

- **Anchor network enhancements:** Additional anchor sites will be added in urban areas, at the western boundary, along transport corridors, near the top of the valleywide layer, and between the surface and valleywide layers. Long-term campaign monitors are supplemented with continuous monitors for nitrate, sulfate, ammonia, and nitric acid (if feasible) at existing sites. Hydrogen peroxide and free radicals will be measured at one non-urban site.

- **Upper air network enhancements:** Additional radar profiler vertical wind monitors, doppler sodar wind monitors, and RASS vertical temperature measurement locations are added to the annual network to better characterize transport and mixing aloft. The Walnut Grove tower is instrumented during this period.

During the 15-days of episodic monitoring, the following measurements will be acquired:

- **Backbone network enhancements:** Twenty-four hour $PM_{2.5}$ duration samples will be acquired for mass concentrations at all sites and for chemical characterization at speciation sites.

- **Satellite network enhancements:** Twenty-four hour $PM_{2.5}$ samples will be acquired for chemical speciation at all satellite sites. Backup filters will be installed to obtain integrated nitric acid and ammonia concentrations.

- **Anchor network enhancements:** Five $PM_{2.5}$ substrate-based samples per day will be acquired at five anchor sites over the periods of 0000-0500, 0500-1000, 1000-1300, 1300-1600, and 1600-2400 PST to include elements, ions (water soluble sulfate, nitrate, ammonium, potassium), and carbon (organic and elemental) by research-grade sampling and analysis systems. Three of these sites will also acquire four samples per day (0000-0500, 0500-1000, 1000-1600, and 1600-2400 PST) to be analyzed for light hydrocarbons, heavy hydrocarbons, carbonyls, and organic particles. The selected periods bracket emissions and meteorological events while allowing sufficient sample to be obtained for analysis (the 1000-1300 and 1300-1600 periods are combined for organic samples to obtain sufficient quantity).

- **Upper air network enhancements:** Remote sensors of upper air winds and temperature will be supplemented with airsondes launched at 0400, 1000, 1200, 1400, 1600 and 2200 PST on each of the fifteen days. These provide continuous relative humidity measurements as well as more detailed wind measurements in the mixed layers.

- **Layer depth variability:** This experiment intends to measure and evaluate the variability of depth in the valleywide layer, and sub-layers when visible, from an aircraft instrumented with down-looking LIDAR. Morning and afternoon flights between upper air monitoring stations on the 15 episode days will provide the information needed to determine how accurate interpolation of layer depth between these stations might be.

- **Chemical composition in the valleywide layer:** This experiment intends to evaluate the changes in concentrations of secondary aerosol and precursors with height in the valleywide layer and to determine how well measurements on towers and hillsides represent these vertical gradients. This might be accomplished by an instrumented hot-air balloon that can make vertical ascents and descents or an aircraft operating in clear air over remote airfields.

- **In situ single particle quantification:** This experiment intends to examine individual particles to determine their formation mechanisms and sources. Time of flight mass spectrometers will be deployed at an urban and non-urban site to quantify the composition and size of individual particles.

- **Fog characterization:** The main purpose of fog characterization is to understand the extent to which fog attenuates $PM_{2.5}$ concentrations by occult deposition. Quantity and composition of fog that deposits to the surface will be measured, as will fog composition in fog droplets of different sizes at different levels of the micrometeorological tower. Less detailed measurements will be taken at the Fresno and Bakersfield sites when fog is present to obtain a horizontal distribution.

1.4.4 Fall Campaign (9/1/2000-10/31/2000)

The fall campaign evaluates contributions to the coarse portion of PM_{10} that is usually caused by excessive fugitive dust contributions. It focuses on a small study area in and around Corcoran, CA, where the highest PM_{10} concentrations have been measured in previous years. The fall campaign will include the following components:

- **PM_{10} backbone network enhancements:** Twenty-four hour duration PM_{10} samples will be acquired everyday on Teflon filters amenable to elemental analysis at the Corcoran and Hanford sites. These will be used to determine how PM_{10} and its coarse fugitive dust fraction throughout this period of traditionally high PM_{10} levels.

- **PM_{10} satellite network enhancements:** Thirty-one satellite sites with portable PM_{10} nephelometers will be operated in and around the Corcoran area to detect dust clouds that move through the area and the contributions from nearby sources. These will be accompanied at five sites by Minivol PM_{10} samplers with Teflon and quartz filters to evaluate chemical composition. Measurements from the continuous monitors will be evaluated every two weeks over the 60-day campaign to determine which sites are hot-spots, and the Minivols will be moved throughout the networks to chemically characterize the PM_{10} at some of these sites.

- **Surface meteorological network enhancements:** Up to five surface meteorological stations will be located within and around the Corcoran satellite network to acquire five-minute average wind speed and wind direction. Measurements from these sites will be compared with the measurements from the long-term station at Corcoran to determine the extent to which it represents transport directions and dust suspension properties induced by meteorology. These measurements will also be used to assign directionality to pulses measured by continuous nephelometers and to relate these pulses to wind erosion during gusts.

- **Upper air meteorological network enhancements:** A sodar will operate near the Corcoran airport to evaluate the evolution of the boundary layer and to quantify the potential transport distances of materials that are suspended above the surface layer.

- **In situ single particle quantification:** This experiment intends to examine individual particles to determine their formation mechanisms and sources. Time of flight mass spectrometers will be deployed for short periods at the Corcoran and Fresno sites to quantify the composition and size of individual particles. The timing, size, and chemical nature of individual particles with a large chemical component will be contrasted between these two sites to evaluate the extent to which urban and non-urban fugitive dust sources affect PM_{10} levels in a large metropolitan area (Fresno) and a nearby rural town (Corcoran).

- **Fugitive dust marker measurements:** Specific markers of different fugitive dust sources will be quantified on 24-hour PM_{10} samples in Fresno, Corcoran, and Angiola to distinguish between specific sources such as road dust, construction dust, and agricultural dusts associated with different crops and farming operations. Sampling and analysis methods for this part of the fall campaign will be finalized after the Fugitive Dust Characterization Study. This will be the first ambient test of chemical and physical markers found in distinct sources that might quantify their contributions to receptors. Marker categories include microscopic size and composition, pesticides, lipids, microbes, and fatty acids.

1.5 Study Design Philosophy

There are many ways to design a field study to accomplish the objectives stated above. CRPAQS field study design is guided by the following tenets:

- Conceptual models of high particle concentrations come before mathematical models. Measurements that refine conceptual models are as important as those to supply mathematical model input and evaluation data.

- A variety of source and receptor models will be used to develop source/receptor relationships and evaluate control strategies. No single existing aerosol model is sufficient to reliably describe annual and episodic particle concentrations in central California. Measurements that support a variety of independent source apportionment methods will be acquired.

- Winter weather and meteorology differ from spring, summer, and fall meteorology and they have not been as intensively studied. Flows are not well-defined or easily measurable, mixed layers are shallow, and residence times are longer. Horizontal and vertical dispersion may dominate over advection. Meteorological measurements in the vertical as well as horizontal are enhanced during winter.

- $PM_{2.5}$ concentrations are highest during winter, and less is known about wintertime meteorology and particle formation mechanisms than is known about non-winter situations. The majority of field study resources are directed toward a winter study to acquire knowledge about this period.

- Much is already known about PM_{10} in central California from prior studies and the existing PM_{10} network is extensive. The coarse particle fraction is largely composed of primary geological material while the $PM_{2.5}$ fraction contains particles directly emitted by combustion sources and secondary aerosol. The $PM_{2.5}$ fraction of PM_{10} is favored for intensive study during the winter when it dominates the PM_{10} and the entire PM_{10} fraction is favored for intensive study in the fall when the coarse particle fraction is large.

- From limited historical data, $PM_{2.5}$ standards are most likely to be exceeded in Fresno and Bakersfield. These areas will be more intensively examined than other parts of central California. Detailed aerosol measurements in these urban areas are preferable to less detail in a larger number of cities. Large spatial coverage is obtained with the satellite site network.

- Primary $PM_{2.5}$ contributions derive mostly from the urban area in which they are measured during winter. Wintertime secondary ammonium nitrate and ammonium sulfate concentrations result from regional-scale transport and mixing of emissions from urban and non-urban areas above a shallow surface layer, but within a valleywide inversion layer. Regional monitoring favors secondary aerosol over primary aerosol.

- Understanding ammonium nitrate formation, sources and precursors takes precedence over understanding ammonium sulfate formation and sources. Sulfate concentrations are much lower than those from other $PM_{2.5}$ components; its sources are well identified and probably the most accurate in the emissions inventory. The ammonium/nitrate/sulfate chemical system is inter-related, so sulfate is not ignored.